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Accretions of Dark Matter and Dark Energy onto $(n+2)$-dimensional Schwarzschild Black Hole and Morris-Thorne Wormhole

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In this work, we have studied accretion of the dark matter and dark energy onto of $(n+2)$-dimensional Schwarzschild black hole and Morris-Thorne wormhole. The mass and the rate of change of mass for $(n+2)$-dimensional Schwarzschild black hole and Morris-Thorne wormhole have been found. We have assumed some candidates of dark energy like holographic dark energy, new agegraphic dark energy, quintessence, tachyon, DBI-essence, etc. The black hole mass and the wormhole mass have been calculated in term of redshift when dark matter and above types of dark energies accrete onto them separately. We have shown that the black hole mass increases and wormhole mass decreases for holographic dark energy, new agegraphic dark energy, quintessence, tachyon accretion and the slope of increasing/decreasing of mass sensitively depends on the dimension. But for DBI-essence accretion, the black hole mass first increases and then decreases and the wormhole mass first decreases and then increases and the slope of increasing/decreasing of mass not sensitively depends on the dimension.

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I. INTRODUCTION

Recent observations of type Ia supernovae indicate that the expansion of the Universe is accelerating rather than slowing down [1–4]. These results, when combined with cosmic microwave background (CMB) observations of a peak in the angular power spectrum on degree scales [5–7], strongly suggest that the Universe is spatially flat with $\sim 1/3$ of the critical energy density being in non-relativistic matter and $\sim 2/3$ in a smooth component with large negative pressure. This acceleration is caused by some unknown matter is known as "dark energy" (DE) [8–11]. Recent WMAP [12] and Chandra X-ray Observations [13] strongly indicate that our universe is undergoing an accelerating phase. The most appealing and simplest candidate for DE is the cosmological constant Λ which is characterized by the equation of state $p = w\rho$ with $w = -1$. Many other theoretical models have been proposed to explain the accelerated expansion of the universe. Another candidate of dark energy is quintessence satisfying $-1 < w < -1/3$ [10, 11]. When $w < -1$, it is known as phantom energy [14] which has the negative kinetic energy. Recently many cosmological models have been constructed by introducing dark energies such as quintessence [10, 11], DBI-essence [15, 16], Tachyon [17], holographic dark energy [18–20], new agegraphic dark energy [21–23], etc.

In Newtonian theory, the problem of accretion of matter onto the compact object was first formulated by Bondi [24]. Michel [25] has formulated the accretion process of steady-state spherical symmetric flow of matter into or out of a condensed object. The accretion of phantom dark energy onto a static Schwarzschild black hole was first formulated by Babichev et al [26, 27] using Michel's process and established that static Schwarzschild black hole mass will gradually decrease to zero near the big rip singularity. Recently, Jamil [28] has investigated accretion of phantom like modified variable Chaplygin gas onto Schwarzschild black hole. Also the accretion of dark energy onto the more general Kerr-Newman black hole was studied by Madrid et al [29] and Bhadra et al [30]. Several authors [31–39] have discussed the accretions of various components of dark energy onto several types of black holes. Now there is a lot of interest of the investigation of dark energy accretion onto static wormhole [40–42]. González-Díaz [43] has discussed the phantom energy accretion onto wormhole. Madrid et al [44] and Martín-Moruno [45] have analyzed a general formalism for the accretion of dark energy onto astronomical objects, black holes and wormholes. Subsequently, the in accelerating universe, the dark energy

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accretion onto wormhole has been discussed in [46, 47].

Recently, there has been a growing interest to study the accretion of higher dimensional black hole (BH). Interest in the BTZ black hole has recently heightened with the discovery that the thermodynamics of higher dimensional black holes [48]. Also, non-static charged BTZ like black holes in $(n+1)$-dimensions have been considered by Ghosh et al [49]. John et al [50] examined the steady-state spherically symmetric accretion of relativistic fluids (like polytropic equation of state) onto a higher dimensional Schwarzschild black hole. Also charged BTZ-like black holes in higher dimensions have been studied by Hendi [51]. By the motivations of above works, we shall assume the accretions of dark matter and dark energy onto $(n+2)$-dimensional Schwarzschild black hole and Morris-Thorne wormhole. The nature of masses of black hole and wormhole will be investigated during various types of dark energies like holographic dark energy, new agegraphic dark energy, quintessence, tachyon, DBI-essence, etc. Finally we present the conclusions of the whole work.

II. ACCRETIONS OF DARK MATTER AND ENERGY ONTO SCHWARZSCHILD BLACK HOLE AND MORRIS-THORNE WORMHOLE

Let us consider $(n+2)$-dimensional spherically symmetrical accretion of the dark energy onto the black hole. We consider a Schwarzschild black hole (static) of mass M which is gravitationally isolated (in geometrical units, $8\pi G = 1 = c$) [50, 52] described by the line element

$$ds^2 = -\left(1 - \frac{\mu}{r^{n-1}}\right) dt^2 + \left(1 - \frac{\mu}{r^{n-1}}\right)^{-1} dr^2 + r^2 d\Omega_n^2 \tag{1}$$

Here, r being the radial coordinate and $\mu = \frac{8M\ \Gamma\left(\frac{n+1}{2}\right)}{n\ \pi^{\frac{n-1}{2}}}$, where, M is the mass of the Schwarzschild black hole. Energy momentum-tensor for the DE, considering in the form of perfect fluid having the EoS $p = p(\rho)$, is

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} \tag{2}$$

where ρ, p are the density and pressure of the dark energy respectively and $u^\mu = \frac{dx^\mu}{ds}$ is the fluid $(n+2)$-velocity satisfying $u^\mu u_\mu = -1$. We assume that the in-falling dark energy fluid does not disturb the spherical symmetry of the black hole.

The rate of change of mass $\dot{M}$ of the Schwarzschild black hole is computed by integrating the flux of the dark energy over the n-dimensional volume of the black hole and given by [50]

$$\dot{M} = -\frac{2\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\ r^n T_0^1 \tag{3}$$

where, A is a positive constant given in [26], which can be written as

$$\dot{M} = \frac{2\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\ AM^n(\rho + p) \tag{4}$$

For quintessence model, $\rho + p > 0$, so $\dot{M} > 0$, i.e., M increases. But for phantom model, $\rho + p < 0$, so $\dot{M} < 0$, i.e., M decreases as Universe expands.

Let us consider $(n+2)$-dimensional spherically symmetrical accretion of the dark energy onto the wormhole. We consider a non-static spherically symmetric Morris-Thorne wormhole metric [53] given by

$$ds^2 = -e^{\Phi(r)} dt^2 + \frac{dr^2}{1 - \frac{K(r)}{r}} + r^2 d\Omega_n^2 \tag{5}$$

where the functions $K(r)$ and $\Phi(r)$ are the shape function and redshift function respectively of radial co-ordinate r. If $K(r_0) = r_0$, the radius r_0 is called wormhole throat radius. So we want to consider the outward region

such that $r_0 \leq r < \infty$. Here we have assumed the redshift function $\Phi(r) = 0$. The rate of change of mass $\dot{\mathbf{M}}$ of the wormhole is given by [46]

$$\dot{\mathbf{M}} = -\frac{2\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\; B\mathbf{M}^n(\rho + p) \tag{6}$$

where B is positive constant. For quintessence model, $\rho + p > 0$, so $\dot{\mathbf{M}} < 0$, i.e., $\mathbf{M}$ decreases. But for phantom model, $\rho + p < 0$, so $\dot{\mathbf{M}} > 0$, i.e., $\mathbf{M}$ increases as Universe expands.

We consider the background spacetime is spatially flat represented by the homogeneous and isotropic $(n+2)$-dimensional FRW model of the universe which is given by

$$ds^2 = -dt^2 + a^2(t)\left[dr^2 + r^2 d\Omega_n^2\right] \tag{7}$$

where $a(t)$ is the scale factor. The Einstein's field equations are given by $(8\pi G = c = 1)$

$$n(n+1)H^2 = 2\rho \tag{8}$$

and

$$n\dot{H} = -(\rho + p) \tag{9}$$

Conservation equation is

$$\dot{\rho} + (n+1)H(\rho + p) = 0 \tag{10}$$

Now assume that the universe is filled with dark matter and dark energy, so $\rho = \rho_m + \rho_D$ and $p = p_m + p_D$. Here, ρ_m and p_m are respectively energy density and pressure of dark matter. Also, ρ_D and p_D are respectively energy density and pressure of dark energy. Now, assume that the dark matter and dark energy are separately conserved. So,

$$\dot{\rho}_m + (n+1)H(\rho_m + p_m) = 0 \tag{11}$$

and

$$\dot{\rho}_D + (n+1)H(\rho_D + p_D) = 0 \tag{12}$$

Now assume that dark matter obeys the equation of state $p_m = w_m \rho_m$ and using the redshift relation $1+z = \frac{1}{a}$ (assume, at present, $a_0 = 1$), we get the solution as

$$\rho_m = \rho_{m0}(1+z)^{(1+n)(1+w_m)} \tag{13}$$

where, ρ_{m0} is the present value of the energy density of dark matter.

Using the equations (8) and (10), equation (4) integrates to yield the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + \frac{4(n-1)\pi^{\frac{n+1}{2}} A M_0^{n-1}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}\;\left(\sqrt{\rho} - \sqrt{\rho_0}\right)\right]^{\frac{1}{n-1}}} \tag{14}$$

where, ρ_0 $(= \rho_{m0} + \rho_{D0})$ is the present value of the density and M_0 is the present value of the Schwarzschild black hole mass. Similar happens for wormhole mass. Using equation (10), equation (6) integrates to yield the mass of the Morris-Thorne wormhole as in the form:

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - \frac{4(n-1)\pi^{\frac{n+1}{2}} B \mathbf{M}_0^{n-1}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}\;\left(\sqrt{\rho} - \sqrt{\rho_0}\right)\right]^{\frac{1}{n-1}}} \tag{15}$$

where, $\mathbf{M}_0$ is the present value of the Morris-Thorne wormhole mass. In the following subsections, we shall assume various types of dark energies like holographic dark energy, new agegraphic dark energy, quintessence, tachyon, DBI-essence, etc.

A. Holographic Dark Energy

In quantum field theory a short distance cut-off is related to a long distance cut-off (infra-red cut-off L) due to the limit set by black hole formation, the total energy in a region of size L should not exceed the mass of a black hole of the same size, i.e., $L^3\rho_D \leq LM_p^2$ (where $M_p^{-2} = 8\pi G = 1$). If the whole universe is taking into account, then the vacuum energy related to this holographic principle is viewed as dark energy, usually called holographic dark energy. The energy density for the holographic dark energy is given by [18–20]

$$\rho_D = 3c^2 L^{-2} \tag{16}$$

where L is the IR cut-off length and c is constant. We assume $L = H^{-1}$. So using equations (8), (13) and (16), we obtain

$$\rho_D = \frac{6c^2\rho_{m0}}{n(n+1) - 6c^2}\ (1+z)^{(1+n)(1+w_m)} \tag{17}$$

From equation (14), we obtain the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + AM_1 M_0^{n-1}\ \left\{(1+z)^{\frac{(1+n)(1+w_m)}{2}} - 1\right\}\right]^{\frac{1}{n-1}}} \tag{18}$$

and from equation (15), we obtain the mass of the wormhole as

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - BM_1 \mathbf{M}_0^{n-1}\ \left\{(1+z)^{\frac{(1+n)(1+w_m)}{2}} - 1\right\}\right]^{\frac{1}{n-1}}} \tag{19}$$

where, $M_1 = \frac{4n(n-1)\pi^{\frac{n+1}{2}}\sqrt{\rho_{m0}}}{\Gamma(\frac{n+1}{2})\sqrt{2[n(n+1)-6c^2]}}$ with $n(n+1) > 6c^2$. The black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 1 and 2 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and holographic dark energy accrete onto black hole and wormhole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass increases and wormhole mass decreases during whole evolution of the Universe. The slope of mass of black hole increases when n increases i.e., mass of black hole increases more sharply for increase of dimensions. Similarly, The slope of mass of wormhole decreases when n increases i.e., mass of wormhole decreases more sharply for increase of dimensions. These are the features of dark matter and dark energy accretions onto black hole and wormhole and natures of increasing/decreasing of mass completely depends on the dimensions. For more dimension, mass of the black hole increases more sharply and mass of the wormhole decreases more sharply for holographic dark energy accretion.

B. New Agegraphic Dark Energy

The energy density of the new agegraphic dark energy is given by [21–23]

$$\rho_D = \frac{3\alpha^2}{\eta^2} \tag{20}$$

where α is a constant and the conformal time $\eta = \int_0^t \frac{dt}{a}$. For simplicity, we assume the power law form of the scale factor, $a = a_i t^m$ where a_i is positive constant and $0 < m < 1$. So we find $\eta = \frac{t^{1-m}}{a_i(1-m)}$. From above we obtain,

$$\rho_D = 3\alpha^2 a_i^2 (1-m)^2\, [a_i(1+z)]^{\frac{2(1-m)}{m}} \tag{21}$$

From equation (14), we obtain the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + AM_2 M_0^{n-1}\ \left[\left\{\sqrt{3\alpha^2 a_i^2(1-m)^2\,[a_i(1+z)]^{\frac{2(1-m)}{m}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]\right]^{\frac{1}{n-1}}} \tag{22}$$

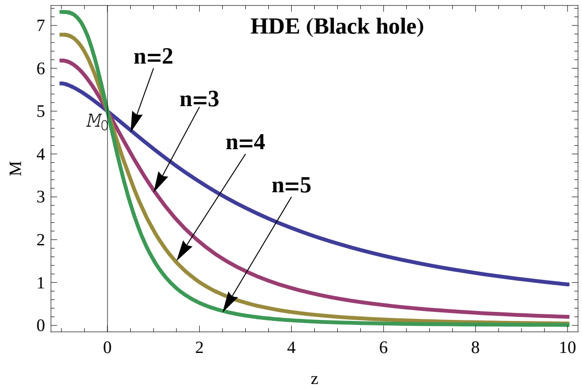

Fig.1

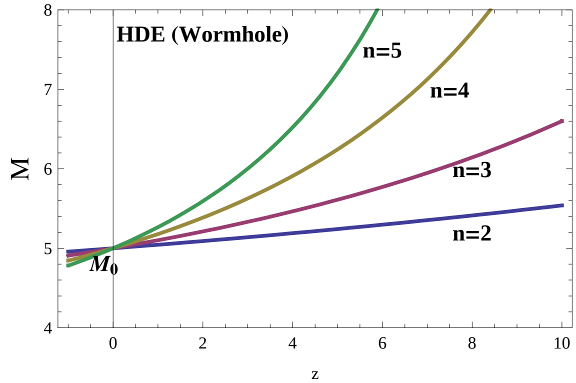

Fig.2

Figs. 1-2 show the variations of black hole mass M and wormhole mass $\mathbf{M}$ against redshift z respectively for holographic dark energy accretion in various dimensions ($n = 2, 3, 4, 5$).

and from equation (15), we obtain the mass of the wormhole as

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - BM_2\mathbf{M}_0^{n-1}\ \left\{\sqrt{3\alpha^2 a_i^2(1-m)^2\left[a_i(1+z)\right]^{\frac{2(1-m)}{m}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{23}$$

where, $\rho_0 = 3\alpha^2(1-m)^2 a_i^{\frac{2}{m}} + \rho_{m0}$ and $M_2 = \frac{4(n-1)\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}$.

The black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 3 and 4 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and new agegraphic dark energy accrete onto black hole and wormhole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass increases and wormhole mass decreases during whole evolution of the Universe. The slope of mass of black hole increases when n increases i.e., mass of black hole increases more sharply for increase of dimensions. Similarly, The slope of mass of wormhole decreases when n increases i.e., mass of wormhole decreases more sharply for increase of dimensions. These are the features of dark matter and dark energy accretions onto black hole and wormhole and natures of increasing/decreasing of mass completely depends on the dimensions. For more dimension, mass of the black hole increases more sharply and mass of the wormhole decreases more sharply for new agegraphic dark energy accretion.

C. Quintessence

The energy density and pressure for quintessence scalar field are [10, 11]

$$\rho_D = \frac{1}{2}\ \dot{\phi}^2 + V(\phi) \tag{24}$$

and

$$p_D = \frac{1}{2}\ \dot{\phi}^2 - V(\phi) \tag{25}$$

where ϕ is the quintessence scalar field and $V(\phi)$ is the potential. If we put the above expressions in the conservation equation (12), we get the wave equation, which contains V and $\dot{\phi}^2$. Now to get the solution of $\dot{\phi}^2$ and V, we need to consider V in term of either ϕ or $\dot{\phi}^2$. If we assume V is some form of ϕ, it is very difficult to obtain the solution of V or $\dot{\phi}^2$. So for simplicity of the calculation, we assume the potential term V is proportional to the kinetic term $\dot{\phi}^2$, i.e., $V = k\dot{\phi}^2$, and we obtain

$$\rho_D = \left(k + \frac{1}{2}\right)\left(C(1+z)^{1+n}\right)^{\frac{2}{1+2k}} \tag{26}$$

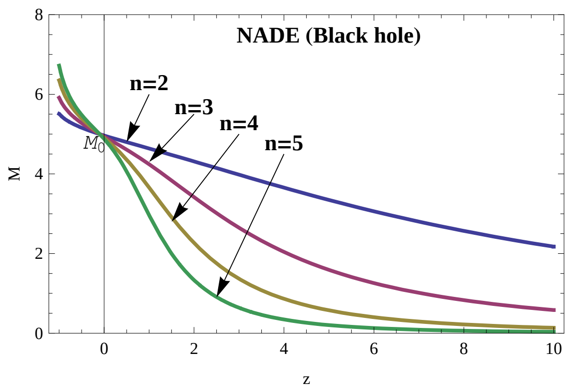

Fig.3

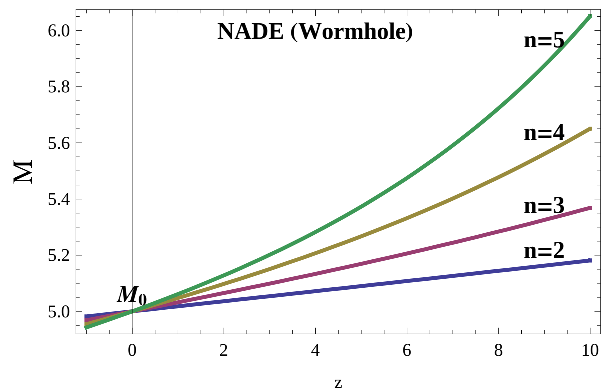

Fig.4

Figs. 3-4 show the variations of black hole mass M and wormhole mass $\mathbf{M}$ against redshift z respectively for new agegraphic dark energy (NADE) accretion in various dimensions ($n = 2, 3, 4, 5$).

From equation (14), we obtain the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + AM_2M_0^{n-1}\ \left\{\sqrt{\left(k+\frac{1}{2}\right)\left\{C(1+z)^{1+n}\right\}^{\frac{2}{1+2k}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{27}$$

and from equation (15), we obtain the mass of the wormhole as

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - BM_2\mathbf{M}_0^{n-1}\ \left\{\sqrt{\left(k+\frac{1}{2}\right)\left\{C(1+z)^{1+n}\right\}^{\frac{2}{1+2k}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{28}$$

where, $\rho_0 = \left(k+\frac{1}{2}\right)C^{\frac{2}{1+2k}} + \rho_{m0}$ and $M_2 = \frac{4(n-1)\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}$.

The black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 5 and 6 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and quintessence dark energy accrete onto black hole and wormhole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass increases and wormhole mass decreases during whole evolution of the Universe. The slope of mass of black hole increases when n increases i.e., mass of black hole increases more sharply for increase of dimensions. Similarly, The slope of mass of wormhole decreases when n increases i.e., mass of wormhole decreases more sharply for increase of dimensions. These are the features of dark matter and dark energy accretions onto black hole and wormhole and natures of increasing/decreasing of mass completely depends on the dimensions. For more dimension, mass of the black hole increases more sharply and mass of the wormhole decreases more sharply for quintessence dark energy accretion.

D. Tachyonic Field

The energy density ρ_D and the pressure p_D of the tachyonic field are [17]

$$\rho_D = \frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}} \tag{29}$$

and

$$p_D = -V(\phi)\sqrt{1-\dot{\phi}^2} \tag{30}$$

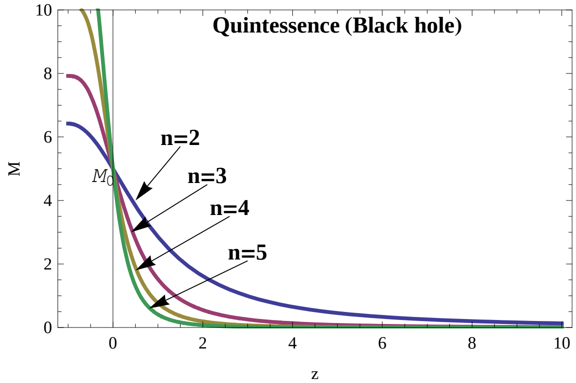

Fig.5

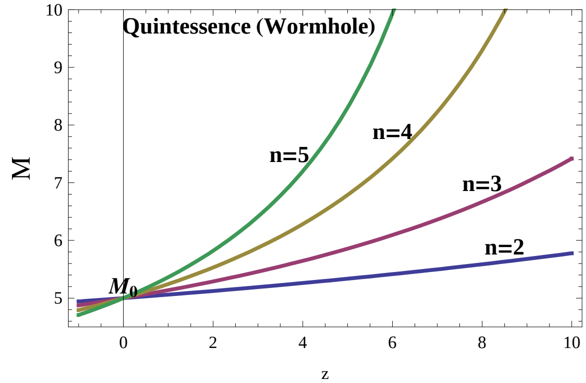

Fig.6

Figs. 5-6 show the variations of black hole mass M and wormhole mass $\mathbf{M}$ against redshift z respectively for quintessence accretion in various dimensions ($n = 2, 3, 4, 5$).

where ϕ is the tachyonic field, $V(\phi)$ is the tachyonic field potential. Put these expressions in the conservation equation (12), we get the wave equation

$$\frac{\dot{V}}{V\dot{\phi}^2} + \frac{\ddot{\phi}}{\dot{\phi}}\left(1 - \dot{\phi}^2\right)^{-1} + (n+1)H = 0 \tag{31}$$

Now, in order to solve the equation (31), we take a simple form of $V = \left(1 - \dot{\phi}^2\right)^{-m}$, $(m > 0)$ [54], so that the solution of V is obtained as

$$V = \left[1 + \left\{C(1+z)^{1+n}\right\}^{\frac{2}{1+2m}}\right]^{m} \tag{32}$$

So from equation (29), we obtain

$$\rho_D = \left[1 + \left\{C(1+z)^{1+n}\right\}^{\frac{2}{1+2m}}\right]^{\frac{1+2m}{2}} \tag{33}$$

From equation (14), we obtain the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + AM_2M_0^{n-1}\left\{\sqrt{\left[1 + \{C(1+z)^{1+n}\}^{\frac{2}{1+2m}}\right]^{\frac{1+2m}{2}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{34}$$

and from equation (15), we obtain the mass of the wormhole as

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - BM_2\mathbf{M}_0^{n-1}\left\{\sqrt{\left[1 + \{C(1+z)^{1+n}\}^{\frac{2}{1+2m}}\right]^{\frac{1+2m}{2}} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{35}$$

where, $\rho_0 = \left(1 + C^{\frac{2}{1+2m}}\right)^{\frac{1+2m}{2}} + \rho_{m0}$ and $M_2 = \frac{4(n-1)\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}$.

The black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 7 and 8 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and tachyon dark energy accrete onto black hole and wormhole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass increases and wormhole mass decreases during whole evolution of the Universe. The slope of mass of black hole increases when n increases i.e., mass of black hole increases more sharply for increase of dimensions. Similarly, The slope of mass of wormhole decreases when n increases i.e., mass of wormhole

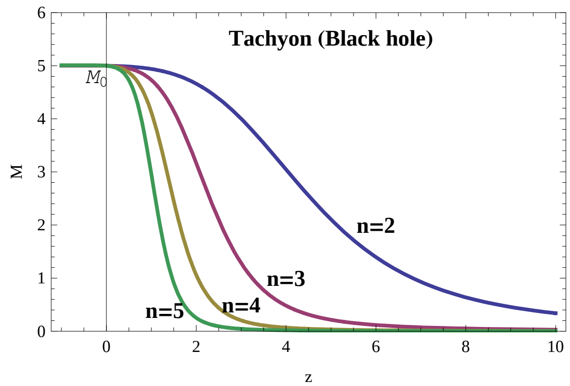

Fig.7

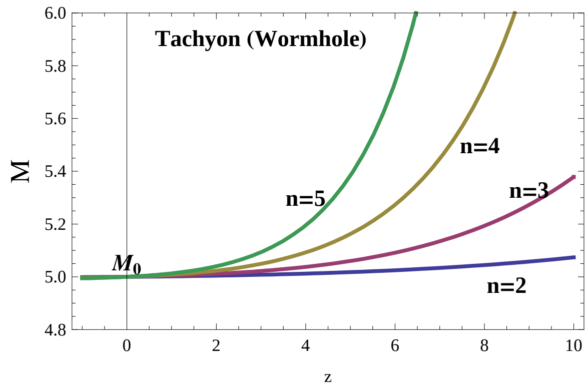

Fig.8

Figs. 7-8 show the variations of black hole mass M and wormhole mass $\mathbf{M}$ against redshift z respectively for Tachyonic field accretion in various dimensions ($n = 2, 3, 4, 5$).

decreases more sharply for increase of dimensions. These are the features of dark matter and dark energy accretions onto black hole and wormhole and natures of increasing/decreasing of mass completely depends on the dimensions. For more dimension, mass of the black hole increases more sharply and mass of the wormhole decreases more sharply for tachyon dark energy accretion.

E. DBI-essence

The energy density and pressure of the scalar field are respectively given by [15, 16]

$$\rho_D = (\gamma - 1)T(\phi) + V(\phi), \tag{36}$$

$$p_D = \frac{\gamma - 1}{\gamma}\, T(\phi) - V(\phi), \tag{37}$$

where the quantity γ is reminiscent from the usual relativistic Lorentz factor and is given by

$$\gamma = \frac{1}{\sqrt{1 - \frac{\dot{\phi}^2}{T(\phi)}}}. \tag{38}$$

where ϕ is the DBI scalar field and $V(\phi)$ is the corresponding potential. From energy conservation equation (12), we have the wave equation for ϕ as

$$\ddot{\phi} - \frac{3T'(\phi)}{2T(\phi)}\,\dot{\phi}^2 + T'(\phi) + \frac{(n+1)}{\gamma^2}\,\frac{\dot{a}}{a}\,\dot{\phi} + \frac{1}{\gamma^3}[V'(\phi) - T'(\phi)] = 0. \tag{39}$$

Let us assume, $\gamma = \dot{\phi}^{-2}$ [55], so from (38) we have $T(\phi) = \frac{\dot{\phi}^2}{1-\dot{\phi}^4}$. Let us also assume $V(\phi) = T(\phi)$. In this case, we have the solutions:

$$\dot{\phi}^2 = \sqrt{1 + \frac{1}{(n+1)\log\frac{C}{a}}} \tag{40}$$

$$V(\phi) = T(\phi) = (n+1)\log\frac{a}{C} \times \sqrt{1 + \frac{1}{(n+1)\log\frac{C}{a}}} \tag{41}$$

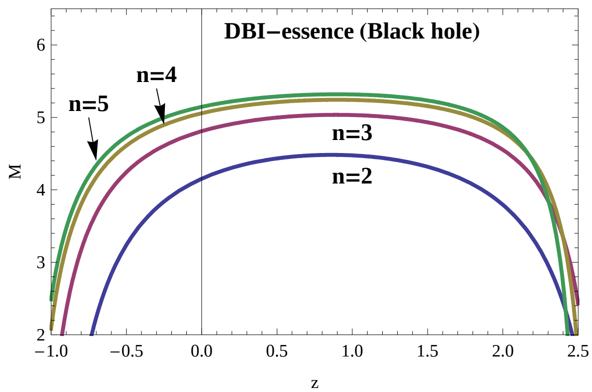

Fig.9

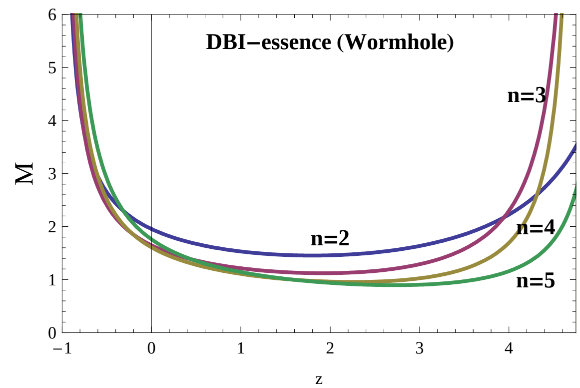

Fig.10

Figs. 9-10 show the variations of black hole mass M and wormhole mass $\mathbf{M}$ against redshift z respectively for DBI-essence accretion in various dimensions ($n = 2, 3, 4, 5$).

where C is the integration constant. Thus from equation (36), we obtain

$$\rho_D = (n+1)\log\frac{1}{C(1+z)} \tag{42}$$

From equation (14), we obtain the mass of the Schwarzschild black hole as

$$M = \frac{M_0}{\left[1 + AM_2M_0^{n-1}\ \left\{\sqrt{(n+1)\log\frac{1}{C(1+z)} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{43}$$

and from equation (15), we obtain the mass of the wormhole as

$$\mathbf{M} = \frac{\mathbf{M}_0}{\left[1 - BM_2\mathbf{M}_0^{n-1}\ \left\{\sqrt{(n+1)\log\frac{1}{C(1+z)} + \rho_{m0}(1+z)^{(1+n)(1+w_m)}} - \sqrt{\rho_0}\right\}\right]^{\frac{1}{n-1}}} \tag{44}$$

where, $\rho_0 = (n+1)\log\frac{1}{C} + \rho_{m0}$ and $M_2 = \frac{4(n-1)\pi^{\frac{n+1}{2}}}{\Gamma(\frac{n+1}{2})}\sqrt{\frac{n}{2(n+1)}}$.

The black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 9 and 10 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and DBI-essence accrete onto black hole and wormhole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass first increases upto a certain finite value and then decreases and wormhole mass decreases upto a certain finite value and then increases during whole evolution of the Universe. These are the features of dark matter and dark energy accretions onto black hole and wormhole for DBI-essence accretion, because our considered model is the phantom crossing model. The natures of increasing/decreasing of mass are nearly similar to all dimensions.

III. DISCUSSIONS AND CONCLUDING REMARKS

A proper dark-energy accretion model for black hole have been obtained by generalizing the Michel theory [25] to the case of black hole. Such a generalization has been already performed by Babichev et al [26, 27] for the case of dark-energy accretion onto Schwarzschild black hole. Astrophysically, masses of the black hole and wormhole are dynamical quantity, so the nature of the mass function is important in our black hole/wormhole model for different dark energy filled universe. Previously it has shown that the mass of black hole increases due to quintessence energy accretion and decreases due to phantom energy accretion. In ref [46], it was shown that for quintessence like dark energy, the mass of the wormhole decreases and phantom like dark energy, the

mass of wormhole increases, which is the opposite behaviour of black hole mass.

In this work, we have studied accretion of the dark matter and dark energy onto of $(n+2)$-dimensional Schwarzschild black hole and Morris-Thorne wormhole. The mass and the rate of change of mass for $(n+2)$-dimensional Schwarzschild black hole and Morris-Thorne wormhole have been found. We have assumed some candidates of dark energy like holographic dark energy, new agegraphic dark energy, quintessence, tachyon, DBI-essence, etc. The black hole mass and the wormhole mass have been calculated in term of redshift when dark matter and above types of dark energies accrete onto them separately. The black hole mass M vs redshift z have been drawn in figures 1, 3, 5, 7 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and holographic dark energy, agegraphic dark energy, quintessence, tachyon accrete onto black hole. For dark matter, we have taken EoS parameter $w = 0.01$. From the figures, we see that black hole mass increases during whole evolution of the Universe. The slope of mass of black hole increases when n increases i.e., mass of black hole increases more sharply for increase of dimensions. On the other hand, the wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 2, 4, 6, 8 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and holographic dark energy, agegraphic dark energy, quintessence, tachyon accrete onto wormhole. From the figures, we see that wormhole mass decreases during whole evolution of the Universe. The slope of mass of wormhole decreases when n increases i.e., mass of wormhole decreases more sharply for increase of dimensions. These are the features of dark matter and dark energy accretions onto black hole and wormhole and natures of increasing/decreasing of mass completely depends on the dimensions. For more dimension, mass of the black hole increases more sharply and mass of the wormhole decreases more sharply for holographic dark energy, agegraphic dark energy, quintessence, tachyon accretion.

Lastly, the black hole mass M and wormhole mass $\mathbf{M}$ vs redshift z have been drawn in figures 9 and 10 respectively for different values of $n = 2, 3, 4, 5$ (i.e., $4D, 5D, 6D, 7D$) when dark matter and DBI-essence accrete onto black hole and wormhole. From the figures, we see that black hole mass first increases upto a certain finite value and then decreases and wormhole mass decreases upto a certain finite value and then increases during whole evolution of the Universe. These are the features of dark matter and dark energy accretions onto black hole and wormhole for DBI-essence accretion, because our considered model is the phantom crossing model. The natures of increasing/decreasing of mass are nearly similar to all dimensions. Hence, we conclude that the black hole mass increases and wormhole mass decreases for holographic dark energy, new agegraphic dark energy, quintessence, tachyon accretion and the slope of increasing/decreasing of mass sensitively depends on the dimension. But for DBI-essence accretion, the black hole mass first increases and then decreases and the wormhole mass first decreases and then increases and the slope of increasing/decreasing of mass not sensitively depends on the dimension.

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